Subsurface Topics

INEEL Subsurface Science Initiative

Idaho National Engineering and Environmental Laboratory

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In This Issue

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SubsurfaceTopics provides technical partners and interested researchers with information and updates about the INEEL's Subsurface Science Initiative and related research.

Vadose Zone Research Park Established

Scientists will have a field-scale research facility when the new Vadose Zone Research Park opens in September 2001. The park will provide scientists with a one-square-mile facility, encompassing two new percolation ponds now under construction. The new percolation ponds will receive about a million gallons of equipment cooling water each day.

> ***" The Vadose Zone Research Park gives us a facility where assumptions and hypotheses can be tested under reasonably controlled conditions. "***

The Big Lost River also flows through the research area. Though the river's flow varies with the season, the Big Lost River is a "losing" stream, losing water to the porous subsurface and eventually disappearing.

"The Vadose Zone Research Park gives us a facility where assumptions and hypotheses can be tested and validated under reasonably controlled conditions," said SSI geoscientist Larry Hull. "This is a tremendous opportunity to advance vadose zone research and significantly enhance INEEL's subsurface science research capabilities."

Hypotheses developed in the laboratory must be tested at progressively larger scales to verify their applicability in the field. The various test beds required for complete testing range from bench-scale experiments conducted in a laboratory, through mesoscale experiments conducted in a high-bay, to field-scale studies where conditions are similar to those encountered at remediation sites.

Monitoring wells have been installed on each side of the Big Lost River. During much of the year, the river is defined only by the grasses in its dry channel.

The research park, at the far end of the test bed spectrum, will provide an area where conceptual models of fluid flow and contaminant transport can be evaluated, new instruments can be installed side-by-side and compared with existing technology, and investigations can be conducted to test hypotheses.

An improved understanding of vadose zone processes will be applied immediately to the INEEL's environmental restoration, waste management and facility operations. For example, to prevent potential flooding of INEEL facilities,

(Research Park, continued on page 2)

Dr. Robert J. Lenhard

New Geosciences Technical Lead Appointed

Dr. Robert J. Lenhard is the new Lead for the Subsurface Science Initiative Geosciences team. Previously a Staff Scientist at Pacific Northwest National Laboratory, Lenhard was responsible for research into multiphase flow and nonaqueous-phase subsurface contamination. His move to the SSI brings invaluable expertise in measurement and modeling of multiphase fluid flow and chemical transport phenomena.

" It is important that our [geosciences] contribution significantly improves DOE's modeling capabilities, particularly the ability to understand and model multiphase flow. "

Lenhard has been a prolific researcher in subsurface science for more than fifteen years. He is best known for work relating to multiphase fluid conduction in porous media. In addition, he developed the first apparatus to measure three-phase

(Lenhard, continued on page 3)

(Research Park, continued from page 1)

water is diverted out of the Big Lost River into old dry lake beds west of INEEL's Radioactive Waste Management Complex. By improving their understanding of how groundwater and contaminants move in a fractured basalt subsurface, scientists will better understand the past effects of floodwaters on the area of buried waste and the current impacts of diverting water from the Big Lost River. In addition, the knowledge will help scientists understand vadose zone issues at DOE sites with similar subsurface structures.

The new percolation ponds in the Research Park will replace percolation ponds located next to the INEEL's Idaho Nuclear Technology and Engineering Center (INTEC) facility. Water seeping from these existing ponds may be resulting in the lateral movement of soil contaminants at that facility. The new ponds are planned to be completed in 2001.

Research area has full instrumentation

A line of monitoring wells and instrumented boreholes, extending almost 3,000 feet from the Big Lost River to the new percolation ponds, has been installed. The wells and boreholes will allow researchers to study the variable recharge from the Big Lost River, the relatively constant recharge from the percolation pond, and the interaction of the two recharge sources. The resulting information will allow researchers to develop a three-dimensional picture of water movement in the subsurface.

Monitoring wells have also been installed on each side of the Big Lost River, allowing scientists to measure water levels and collect samples when perched water zones form. With this information, scientists will be able to study how perched water levels respond to the river's variable flow.

The monitoring wells are equipped with an array of sensors that use electrical resistivity tomography to measure changes in the water's movement. The sensors derive a three-dimensional image of the electrical resistivity of the subsurface by taking advantage of water's ability to conduct electricity much more readily than rock. Geophysical instruments will also be used in the monitoring wells to remotely-measure material properties.

Boreholes have been drilled in areas where the basalt and sediments are not saturated. At the locations where perched water is expected to form or where water was observed while drilling, instrument packages were installed in the boreholes to monitor water movement outside the boreholes.

The typical instrument setup includes a water content sensor, tensiometer, suction lysimeter and a gas port. The instruments are attached to a 1 in. PVC pipe to support the instruments and to permit access to the tensiometer to service the pressure transducer.

The instrument packages–typically containing a water content sensor, tensiometer, suction lysimeter and a gas port–have been installed at several depths in each instrumented borehole. The tensiometers and water content sensors will determine if water is moving through the sedimentary layers or around the sediments. The suction lysimeters and gas ports will monitor the liquid and gas phase chemistry in the unsaturated rocks.

A good connection between the instruments and surrounding rocks was established by packing a fine sand around the instruments. The boreholes were then sealed, by placing expanding clay between each set of instruments and the surface, to ensure that water cannot migrate down the boreholes.

The research park and percolation ponds are scheduled to be completed during the summer of 2001. Data collection will begin immediately so information on background conditions in the subsurface can be gathered before the ponds are put into service. The background data will provide the basis for quantifying the changes that take place in the vadose zone as water from the percolation ponds is added to the subsurface.

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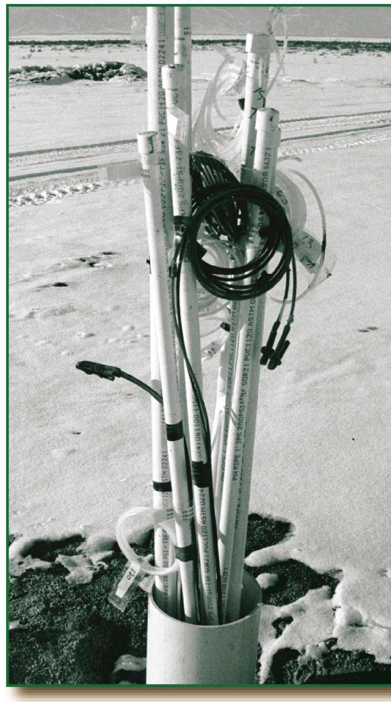

Though the instruments are temporarily exposed at the surface, a surface casing and metal well box are installed to protect them. The instruments are connected to data loggers that will record moisture content, temperature and water pressure readings.

Recruiting Effort Continues

Though several key positions have filled, several technical leads and advisory scientist positions are still open. Technical leads are responsible for developing research programs for their respective disciplines, within the context of the overarching goals and vision of the Subsurface Science Initiative. Technical leads also have the responsibility of developing strategic and tactical plans for building and maintaining business in their area of the Subsurface Science Program, and managing interdisciplinary, multi-institutional subsurface research.

Technical lead positions remain open for:

- Biosciences
- Modeling
- Chemistry

(Lenhard, continued from page 2)

air-oil-water saturation-pressure relations. Lenhard has published numerous articles in technical journals, including the *Water Resources Research, Transport in Porous Media, Advances in Water Resources* and *Journal of Contaminant Hydrology*.

"Geosciences have a fundamental role in the Subsurface Science Initiative," says Lenhard. "It is important that our contribution significantly improves DOE's modeling capabilities, particularly the ability to understand and model multiphase flow. Modeling non-linear phenomena like this is a significant challenge."

Lenhard believes that additional research is needed to better understand coupled processes affecting contaminant fate so that more effective remediation strategies and technologies can be developed for the DOE. An objective is to reduce the uncertainty in subsurface fluid flow and chemical transport predictions.

Currently, Lenhard is in the process of developing a model to predict the residual, i.e., non-drainable, NAPL (non-aqueous phase liquid) saturation in the vadose zone as a function of saturation-path histories. Testing of the model will be conducted in collaboration with Pacific Northwest National Laboratory. The goal is to obtain more accurate predictions of NAPL behavior in the vadose zone using numerical multiphase flow codes.

Lenhard said his decision to join INEEL was influenced by the research opportunities offered by the Subsurface Science Initiative.

"It's hard to pass up an opportunity to work with an inter-disciplinary multi-institutional program, particularly one that so closely aligns with my own research interests."

Lenhard was hired as the Geosciences Discipline Leader for the Subsurface Science Initiative in January 2001.

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DOE Complex-Wide Vadose Zone Science & Technology Roadmap Project

Executive Committee

Chair: Dan Stephens,
DB Stephens & Assoc.
Co-chair: Steve Kowall, INEEL
Frank Parker, Vanderbilt U.
Lorne Everett, IT Group
Ed Weeks, USGS
Carl Enfield, EPA
Cathy Vogel, DoD
John Wilson, New Mexico Tech
Darwin Ellis, Schlumberger
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Vice Chair: Everett Springer, LANL
Brent Newman, LANL
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Pat Brady, SNL
Alan Flint, USGS/WRD
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Bill Murphy, EarthWorks
Harold Vinegar (consultant), Shell
Annette Schafer, INEEL
Rosemary Knight (consultant)
Tim Scheibe, PNNL
Don Steeples, U. of Kansas

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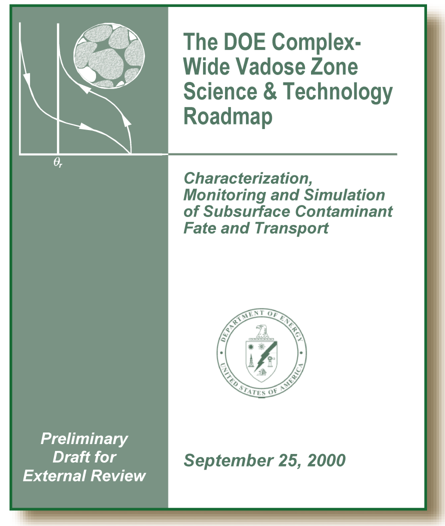
Vadose Zone Roadmap Nears Completion



*The draft **DOE Complex-Wide Vadose Zone Science & Technology Roadmap** is available online at **http://www.inel.gov/vadosezone/***

The National Vadose Zone Program released its preliminary draft roadmap for comment on September 25, 2000. When finalized, the roadmap will guide DOE's national research priorities for understanding the subsurface by setting national science and technology research goals for the vadose zone over the next 25 years. The objective is better and more cost-effective management of vadose zone contamination.

The National Vadose Zone Program used a roadmap format to identify knowledge gaps and to determine which of them must be filled to reach a desired outcome. The format provides a framework to improve DOE's understanding and modeling of the vadose zone and subsurface contaminant behavior.

The draft proposes three categories of research that will contribute to an improved scientific understanding: basic subsurface processes; data collection and monitoring capabilities; and computer models, predictive capabilities, and data visualization techniques.

*" **A far-reaching goal allows for larger gains.** "*

DOE has the difficult task of ensuring the safety of hazardous and radioactive waste sites for centuries. According to Daniel Stephens, Chair of the Vadose Zone Executive Committee, a discipline-integrated vadose zone research program is likely to substantially advance the understanding and ability to more confidently predict subsurface behavior during long term stewardship at DOE facilities.

"The roadmap is a major first step in focusing DOE R&D resources toward a specific goal," Stephen Kowall, Vice Chair of the Executive Committee said. "This is a map drawn in broad strokes. Nevertheless, it provides the first guidance at a federal level."

Kowall believes that setting a far-reaching goal will allow for larger gains in a mapped direction.

Roadmap development a result of broad involvement

The INEEL was charged by DOE to lead the development of the roadmap. To ensure that the roadmap's recommendations represented a consensus, the INEEL worked with sixty-two representatives from universities, industry, and government agencies, including the EPA, USDA, DoD, and the USGS. Less than 10% of the development group represented the INEEL. The team included internationally recognized vadose zone experts and authors of most of the available vadose zone literature.

The team met for six months, beginning the process by asking, *What needs to be done in vadose zone research that can't be done now?* Then, they moved through a four-step process to construct the roadmap.

Kowall said that the four steps are: 1) considering the problem set, 2) deciding what you need that you don't have, 3) establishing goals for improvement, and 4) challenging the vadose zone community in industry, academia and the government sector to reach the goals.

"After examining the problem set, you must identify any missing capabilities," Kowall added, "then calculate what the pathways are between where you are and where you want to be."

Roadmap is policy tool for a relatively new scientific field

The team's product–the vadose zone roadmap–is a policy tool that challenges the vadose zone community to help fill in the gaps according to the pathways charted in the roadmap.

"This challenge is different from a science and technology 'push goal,' which is a desire for science for science's sake," Kowall pointed out. "This is a 'pull goal,' which encourages advances in science to solve problems identified as essential to reaching a targeted outcome."

" This [challenge] is a 'pull goal,' which encourages advances in science to solve problems... "

According to Stephens, the first graduate courses in this field were offered only in the early 1980s, just 20 years ago. Until then, most of those interested in studying the subsurface followed one of two paths, focusing either on groundwater hydrology or soil science.

"Much of what scientists have come to learn about the vadose zone has been achieved only in the last 25 years or so," Stephens stated. "Undoubtedly, a great deal of discovery of new processes has yet to occur."

Reducing uncertainty is major objective

Until recently, contaminants in the vadose zone were believed to be relatively immobile. Very little attention was given to understanding the nature of the vadose zone, the potential pathways for fluids or contaminants to disperse throughout the zone, or the myriad possible interactions among fluids, contaminants, and the chemical, biological and physical components of the vadose zone.

However, new discoveries of hazardous and radioactive chemicals migrating through the vadose zone and entering underlying aquifers have changed many assumptions, both about the vadose zone and the importance we place on understanding this region.

"Uncertainty," Kowall said, "is one of the major problems DOE faces when making decisions."

"When regulators investigate contamination sites," Kowall explained, "they apply a risk calculation to determine what actions are needed in regards to the contamination:

[Risk = contaminant exposure • contaminant toxicity • contaminant concentration]

Kowall continued, "The exposure is set by the regulators, the toxicity is assessed by the health profession and the concentration is determined by subsurface scientists."

Because it is impracticable and costly to remove wastes hundreds of feet deep in heterogeneous media, the ability to monitor and predict contaminant behavior in the vadose zone becomes all the more urgent.

Existing abilities to monitor and predict fluid flow and contaminant transport processes in the vadose zone are limited by a poor understanding of many fundamental interactions, as well as by a general lack of methodologies necessary to

(Roadmap, continued on page 6)

(Organization, continued from page 4)

Physical Processes Workgroup

Chair: Martinus Th. van Genuchten, USDA
Vice Chair: Brian Looney, SRS
Fred Brockman, PNNL
Leslie Smith, U. of BC, Vancouver
Markus Flury, Washington State U.
Robert Smith, INEEL
Bill Glassley, LLNL
Peter Lichtner, LANL
Bob Lenhard, INEEL
Ed Sudicky, U. of Waterloo, Canada
Dani Or, Utah State U.
Kate Scow, UC-Davis
Andy Tompson, LLNL
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Simulation and Modeling Workgroup

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Todd Arbogast, University of Texas, Austin
Cass T. Miller, UNC
Jirka Simunek, U. of California, Riverside
Boris Faybishenko, LBL
Andy Felmy, PNNL
Wendy Soll, LANL
Tim Ginn, UC Davis
Laura Toran (reviewer), Temple U.
Larry Hull, INEEL
Alexander M. Dykhne, Russian Academy of Sciences

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Initiative Notes

VEGAS scientist speaks at INEEL

On April 4, 2001, Rainer Helmig, of the VEGAS Institute in Stuttgart, Germany, gave a presentation to researchers from the INEEL's Subsurface Science Initiative and others on "*Upscaling Techniques for Two-Phase Flow Processes in Porous Media*." The event was sponsored by the University of Idaho and held on the Idaho Falls campus.

Subsurface Science Initiative now online

The Subsurface Science Initiative website (**http://subsurface.inel.gov**) was externally launched in April together with a redesign of INEEL's overall web presence.

Los Alamos engineer to lead INRA

Dr. Gautam Pillay, a chemical engineer and administrator, recently assumed the position of executive director of the Inland Northwest Research Alliance. INRA, composed of seven regional universities, is a partner in Bechtel BWXT Idaho, the prime contractor at the INEEL. Prior to assuming his new position, Pillay was the special assistant to the deputy laboratory director for Science, Technology and Programs at Los Alamos National Laboratory.

Job postings for the Subsurface Science Initiative are on the Internet at **http://jobs.inel.gov/**

Qualified candidates are invited to send their CV with a cover letter detailing their scientific, administrative and leadership qualifications to:

Subsurface Science Initiative
Research Search Committee
c/o Russel Hertzog
Idaho National Engineering
and Environmental Laboratory
P.O. Box 1625
Idaho Falls, ID 83415-2203

(Roadmap, continued from page 5)

represent flow and transformation processes across different spatial and temporal scales in highly heterogeneous media. Because of the large uncertainties inherent in existing techniques, there is currently no acceptable technical basis for regulatory oversight of the vadose zone.

Kowall believes that the problem with determining the contaminant concentration is that the vadose zone is so complex and is so little understood; each measurement contributing to the scientist's final recommendation to the regulators has some degree of uncertainty. Any decision then made by the regulators, based even partially on that recommendation, is affected by that uncertainty.

The roadmap has been designed to reduce this uncertainty through greater organized research into the vadose zone. Subsurface researchers will be able to make more precise recommendations to the regulators who will then, in turn, make more informed decisions about remediation, waste handling and long-term stewardship.

Scaling research given high priority

Research into scaling, moving from lab-, to meso-, to field-scale, was given high priority in the roadmap.

"You could perform a lab test on chemical movement through sand in a test tube and record one set of data, but if you actually traveled to the desert and poured that same chemical on the ground, the transport of the chemical through the vadose zone would be different," Kowall explained.

" Due to its complexity and the challenges associated with that complexity, the vadose zone [has been] easy to ignore. "

Mesoscale testing, which is one SSI focus, would help fill this gap. Research at the mesoscale would include development of scaling techniques in realistic and varied environments.

According to Kowall, the roadmap envisions multidisciplinary scaling of constitutive theories; massive enhancements in deterministic and stochastic tools; hierarchal frameworks for multiple scales of observation/measurement; and comprehensive error analysis and adaptive scaling methods.

"Without the development of the roadmap," Kowall commented, "the vadose zone would not be given the attention it deserves. Due to its complexity and the challenges associated with that complexity, the vadose zone is easy to ignore."

While the research called for in the roadmap will be a focus of the SSI, the INEEL's Subsurface Science Initiative will have to compete for funding on an equal basis with other laboratories, academia and industries. As Kowall pointed out, "The roadmap is a leadership effort."

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Mobile Laboratory Expands Field Capabilities

New SSI mobile laboratory

Between the heat, cold, dust and dirt, it can sometimes be difficult for scientists to collect and process subsurface samples in the field. With the help of SSI's Geosciences Research group, a new 26-foot mobile field laboratory is now available. The laboratory will provide scientists with the capability of preparing samples in a clean facility and is expected to significantly increase the ability of scientists to conduct high-quality research.

" The mobile lab gives us capabilities similar to a fixed lab facility at a field site. "

Hydrochemist Travis McLing, a principal scientist in the Geosciences Research group, made sure that the mobile laboratory was planned for a range of uses. He asked microbiologists, field hydrologists, geologists and other scientists to list their requirements and then entered their comments into a database to discover which requirements were most frequently requested.

McLing says that he started at the top of the wish list when deciding what to put in the trailer. His decisions were based on providing tools that could be used by the greatest number of people. "Everyone can use almost everything in the lab," McLing says, "though no one is getting everything they wanted."

For instance, hoods were a universal request. But when the choice came down to a box-end wrench or a crescent wrench, McLing had to choose the crescent wrench. Although the box-end wrench might be the best tool for some jobs, the crescent wrench is adequate and can be used in more situations.

Planning, purchasing and fully outfitting the $75 thousand mobile laboratory took six months. It contains a variety of tools: from refrigerators and a high-vacuum wet chemistry system, to self-contained gas chromatograph vents, areas for acid storage and communications hookups.

"The mobile lab gives us capabilities similar to a fixed lab facility at a field site," says McLing. "There are special counter tops and floors of epoxy resin to resist chemical spills. We have a complete reverse-osmosis, de-ionized water system. Because of these capabilities, we can prepare samples and conduct initial analysis on-site, and then transport the samples–intact and adequately preserved–back to the lab for full analysis."

The mobile laboratory will be used for field studies and site characterizations at the INEEL and other DOE sites across the country. It is anticipated the laboratory will be used at any given site for six to nine months–the average length of time for a field campaign–for an average of two research campaigns each year. The laboratory is already scheduled for use this summer at the INEEL's new Vadose Zone Research Park.

Mobile lab scheduled for use in study of metal attenuation in contaminant plumes

The SSI's geomicrobiologists want to learn whether it is feasible to use naturally-occurring microbes to facilitate metal attenuation in contaminant plumes.

Scientists will inject a dilute solution of urea with a bromide tracer into the aquifer. After the amendments are allowed to react for a given time, samples will be retrieved and analyzed. Their objective is to learn whether microbial utilization of urea can raise the pH of the groundwater, increasing calcite precipitation.

The contaminants that co-precipitate within the calcite mineral structure are of particular interest to the scientists. It is possible that some radioactive metals, such as strontium-90, could replace the calcium in the calcite structure. If so, these contaminants would be effectively locked up and removed from the groundwater. If the reaction can be speeded up, the research may give scientists new tools to clean up contaminant plumes.

"We are interested in finding out how well this particular use of in-situ bioremediation works. If we can determine that it is feasible on a large-scale," McLing says, "microbiologists might be able to apply this cleanup process on groundwater contaminated with strontium-90. Any time you can do something in-situ, it's a lot less expensive than pump-and-treat technology. The mobile lab gives us the ability to conduct our tests efficiently."

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Conceptual Design of Subsurface Geosciences Laboratory to begin

The proposed Subsurface Geosciences Laboratory is one step closer to reality. In May 2001, INEEL began the bidding process to award a contract for a conceptual design to an architectural and engineering firm with laboratory design experience.

Congress has appropriated $400,000 for this effort, to be released upon completion of the Technical and Functional Requirements document describing facility needs. The final conceptual design for the new facility is scheduled to be complete by January 2002.

$5 million Awarded for Eastern Idaho Science and Research Center

The State of Idaho awarded $5 million to the University of Idaho and Idaho State University for the construction of a new science and technology center in eastern Idaho. The facility will be built at their joint satellite campus in Idaho Falls. Groundbreaking was scheduled for May 2001. The 50,000-square-foot facility will provide workspace for education programs and specialized research and development including support of the Subsurface Science Initiative.

Idaho Gov. Dirk Kempthorne said he expects the facility to advance most of the strategic initiatives identified by his Science and Technology Advisory Council, headed by Bill Shipp, the INEEL Laboratory director.

"This facility will be a tremendous public and private partnership," Kempthorne said. "Students will be learning under the same roof where researchers are developing the next generation of cutting-edge technologies–technologies our industries can use to create new jobs."

Once completed, the facility's operating funds will come from grants, lease fees and other income. The facility is projected to house 90 direct employees and average $7.5 million in annual grant revenue, as well as supporting master's doctoral and post-doctoral research.

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